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AUTHOR Capa, Yesim; Yildirim, Ali; Ozden, M. Yasar
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ABSTRACT

The aims of this study were to diagnose students' misconceptions concerning photosynthesis and respiration in plants, and to investigate reasons behind these misconceptions. The subjects were 45 ninth grade high school students and 11 high school teachers. Data were collected by interview technique. All of the interviews were audiotaped and transcribed verbatim by the researcher. Misconceptions were analyzed under the headings of plant nutrition, role of water in plants, role of leaves in plants, gas exchange, energy transformation, the definition and the importance of photosynthesis, role of light in photosynthesis, respiration in plants, and the relationship between photosynthesis and respiration in plants. Findings indicated that many students have misconceptions about photosynthesis and respiration in plants. These misconceptions were found to be generally based on social practices and school experiences involving students' learning styles and instruction. (Contains 15 references.) (Author/YDS)

Y. Capa

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AN ANALYSIS OF STUDENTS' MISCONCEPTIONS CONCERNING PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

Yesim CAPA, The Ohio State University

Ali YILDIRIM, Middle East Technical University

M. Yasar OZDEN, Middle East Technical University

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(correspondence to capa.1@osu.edu)

Abstract

The aims of this study were to diagnose students' misconceptions concerning photosynthesis and respiration in plants, and to investigate reasons behind these misconceptions. The subjects were 45 ninth grade high school students and 11 high school teachers. Data were collected by interview technique. All of the interviews were audiotaped and transcribed verbatim by the researcher. Misconceptions were analysed under the headings of plant nutrition, role of water in plants, role of leaves in plants, gas exchange, energy transformation, the definition and the importance of photosynthesis, role of light in photosynthesis, respiration in plants, and the relationship between photosynthesis and respiration in plants. Findings indicated that many students have misconceptions about photosynthesis and respiration in plants. These misconceptions were found to be generally based on social practices and school experiences involving students' learning styles and instruction.

AN ANALYSIS OF STUDENTS' MISCONCEPTIONS CONCERNING PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

The fundamental aim of science education is to make students construct stable and meaningful organization of concepts in their frameworks. However, it should be emphasized that students' prior knowledge is very important while constructing and organizing concepts. This is well stated by Ausubel (1968) with the following statement: "If I had to reduce all of the educational psychology to just one principle, I would say this: The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (p. iv). This statement has led to many studies about the effect of prior knowledge on subsequent learning.

Moreover, these existing conceptions might be incompatible with those accepted in science. These are called as *misconceptions*, which make the learning of science difficult.

For the past two decades, misconceptions have become major concern of biology educators. The concepts studied include respiration (Sanders, 1993); photosynthesis (Haslam & Treagust, 1987); genetics (Browning & Lehman, 1988); ecology (Adeniyi, 1985); and circulatory system (Arnaudín & Mintzes, 1985). Findings indicate that students hold many misconceptions concerning these concepts. Biology may be generally considered as a conceptual system, in which most of these concepts are related to each other. For example, without understanding the process of photosynthesis, students could not effectively learn the differences between producers and consumers, events in food chains and food webs. However, meaningful understanding of ecology requires understanding of these processes as prerequisites (Anderson, Sheldon, &

Dubay, 1990). Furthermore, if students do not construct acceptable concepts in a meaningful manner, this may lead to the formation of misconceptions.

The characteristics of misconceptions have been also described by many researchers as prevalent (Amir & Tamir, 1992; Fisher, 1985); sensible to the children who hold them (Benson, Wittrock, & Baur, 1993); highly resistant to be changed at least by traditional teaching methods since they are strongly rooted in students' prior experiences (Fisher, 1985; Lumpe & Staver, 1995); have historical precedence; that is they reflect ideas supported by early scientists (Fisher, 1985; Wandersee, 1985).

Furthermore, several studies on misconceptions held by students showed that misconceptions might come up as a result of both in- and out-of-school experiences (Adeniyi, 1985; Fisher, 1985; Gilbert, Osborne, & Fensham, 1982). By taking the sources of misconceptions into account, misconceptions should be remedied in order to achieve meaningful learning. However, it is difficult to identify students' misconceptions and to remediate them during instruction at the same time. For that reason, the first thing to do is to identify misconceptions.

Misconceptions could be assessed quantitatively via an objective test with distracters representing possible misconceptions related to the concepts being tested (Doran, 1972). Besides, interview technique has been also used for data collection in research studies, because during interviews students' initial answers to questions can be probed further (Adeniyi, 1985). Moreover, it has been proved to be a remarkably powerful way of understanding how children describe and explain the world around them. It allows as much freedom of expression as possible for the child (Lythcott & Duschl, 1990).

Different types of methods were used by Amir and Tamir (1992), Haslam and Treagust (1987), Roth and Anderson (1985), and Wandersee (1985) to diagnose students' misconceptions concerning photosynthesis and respiration in plants, and their findings could be summarized under the following headings:

- a) Plant nutrition
- b) The role of water in plants
- c) The role of leaves in plants
- d) Gas exchange
- e) Energy transformation
- f) Definition and importance of photosynthesis
- g) The role of light in photosynthesis
- h) Respiration in plants
- i) The relationship between photosynthesis and respiration in plants

The purpose of this study was two fold: to identify ninth grade Turkish students' misconceptions concerning photosynthesis and respiration in plants, and to investigate reasons behind these misconceptions. Headings listed above form the main frame of analysis. Although extensive research had been done in many countries for this phenomenon, it has not yet been questioned in Turkey. Findings are crucial in Turkey not only for science/biology teachers, but also for curriculum developers. Thus, they can organize intended learning outcomes by taking findings into account.

Method

Participants

This study contained two groups of samples: One of them includes 45 ninth grade students who enrolled in a large high school; and the other 11 high school biology teachers in Turkey. Both teachers and students were selected purposively. Voluntary involvement in research was taken into consideration while selecting participants in order to ensure consistency.

Data Collection

In this study, two semi-structured interview schedules were used to collect data. One was designed for students and the other one for teachers.

Student Interview Schedule. This schedule consisted of two parts. The first part was used to identify misconceptions, whereas the second part was used to investigate sources of these misconceptions. To prepare the first part of the interview schedule, literature related to students' misconceptions concerning photosynthesis and respiration in plants unit was examined. Misconceptions related to those topics were listed. Additional misconceptions, which were observations of the researchers, were included in the list. These were transformed into question format. Then, the draft was improved by contributions of a science education researcher and high school biology teachers. The final draft included 22 open-ended questions. The second part of the interview schedule was prepared according to students' responses during interviews. It consisted mainly of open-ended questions in order to explore students' reasoning behind their misconceptions.

Teacher Interview Schedule. This schedule was designed after the data were collected about students' misconceptions in photosynthesis and respiration in plants through student

interviews. After the transcription of the interviews with students, misconceptions identified were listed. Based on this list of misconceptions, teachers were asked the probable reasons of the specified misconceptions.

Interviews conducted with students and teachers were audio taped and transcribed verbatim by the researcher.

Data Analysis

Diagnosis of misconceptions. So as to analyze the interviews done with students to diagnose misconceptions, the first step was to group questions according to headings listed before. Students could produce several different responses to each question; therefore for each question, the responses given by students were identified and listed. Categories, into which students' responses would be grouped, were identified and named. The placement of students' responses in each category was done by two researchers independently, any disagreements were discussed and a joint decision was taken.

Reasons of misconceptions. To analyze interviews done with teachers and students to investigate sources of misconceptions, 'start list' of codes were created based on the review of literature. Then interview transcripts were examined in order to make necessary additions, deletions, and revisions. Students' and teachers' responses were examined by two researchers based on the final codes appeared.

Results

Diagnosis of misconceptions

This study indicated that most of the Turkish students have misconceptions concerning photosynthesis and respiration in plants. The most common misconceptions identified in this study by interview technique are depicted in Table 1. Generally, results are consistent with those obtained in other countries.

Insert Table 1 here

Here are some examples of selected headings from this study:

Mostly (84% of the students) held misconception about plants' food. Students were not aware of plants' ability to produce their food. Students generally considered the materials taken from outside like water, minerals, soil, sun etc. as food for plants. They were unaware of the difference of plants from other living organisms particularly from themselves. A few examples can be given from the interview excerpts of students regarding water as plants' food:

Researcher: What is plant's food?

Student 1: Water. They need water to live. As our organism requires water, it is also necessary for their organisms to work properly.

Researcher: You told that water is food for plants. How do you know this?

Student 2: Plants could not take solid materials into their body since they don't have mouth like other living organisms. They only have pores. Thus, they will take water as food.

Moreover, when students were asked about plants' activity in autumn, only 9% of them gave satisfactory answer. One group of students reported that plants continue to make photosynthesis in autumn. Following excerpts are examples to this situation:

Researcher: In autumn, do plants make photosynthesis?

Student 1: They make. Because, they still require this process. Moreover, chlorophyll molecule does not disappear.

Student 2: They should make photosynthesis in order to survive.

Another group of students who stated that they couldn't make photosynthesis were asked to explain their food at those times. They listed their food as rain, soil, and minerals taken from soil. These responses are consistent with the responses given for the plant's food. Remaining group told: "Plants die in autumn, so they don't require food".

In addition, students' description of photosynthesis was investigated by different questions. Photosynthesis can be scientifically defined as "a process in which the autotrophic organisms produce organic materials (compounds that are produced by organisms such as carbohydrates) from inorganic materials (CO_2 and H_2O) using sunlight energy harnessed by the chlorophyll". Students' answers were analyzed according to this definition.

Some students' responses (25%) indicated that they regarded photosynthesis as only a gas exchange process. Typical answers were "By the help of sun light, CO_2 is converted into O_2 ", "the process of taking in CO_2 and giving out O_2 in the daylight by plants", "the ability of taking in CO_2 and giving out O_2 ". Moreover, it was revealed that that half of the students could define photosynthesis satisfactorily, however when they were asked further questions in order to

investigate their understanding, their answers showed that they had only memorized a definition without making sense of the concept.

When students were asked, "Where does photosynthesis take place?", approximately 26% of them gave the scientifically accepted answer. On the other hand, more than half of the students told that photosynthesis occurs at only leaves; the remaining replied 'only stem' as site for photosynthesis. Here are the examples from interview excerpts:

- Student 1: Since stomata or gas exchange pores are in the leaves, it should occur there.
- Student 2: Since the chlorophyll is in the leaves, it should occur there.
- Student 3: In stem...because I identify plants like people. As we have our lungs within our body, they have their similar organs in their stem too.
- Student 4: It can't be at roots because sunlight can't reach there; it can't be at leaves because it makes excretion from there so that it should be at stems

Additionally, almost all students knew the importance of light for photosynthesis and the factors that affect the rate of photosynthesis. However, they had problems with the concept of limiting factor. They were asked, "If I increase the light intensity continuously, does also rate of photosynthesis increase accordingly? What happens? Why?" 20% of the students gave correct response which was "If other factors affecting photosynthesis are not adequate, it will not increase." On the other hand, half of them told that it would not increase because high intensity of light would give harm to plant after some point. Examples to this situation are given as follows:

- Student 1: Once I was growing a plant and it took too much sunlight, it began to dry. When I took it from sunlight, it turns to normal.
- Student 2: I thought myself. It is also a living organism. When I take high intensity of light, it makes a bad effect to me, thus it will also make bad effect to the plant.
- Student 3: It will not increase because it will make photosynthesis as needed, not more than enough

Moreover, students were asked series of questions in order to explore their understanding of respiration. Most of the students (84% of total) knew that plants make respiration. However, more than half stated that respiration in plants occurs at nights. Other alternative responses were 'during photosynthesis' and 'whenever breathing is required'.

Exploring sources of misconceptions

Broadly speaking, interviews with students and teachers demonstrated that the sources of these misconceptions are:

1. School Experience
 - a. Instruction including textbook effect, transmission by teacher, and inadequacy of instruction.
 - b. Inadequacy of Curriculum
 - c. Memorization of isolated pieces of information.
 - d. Wrong descriptions of the observations in school.
 - e. Students' experiences related to other science courses including primary and secondary school experiences.

2. Social practices

- a. Students' own judgments based on their observations.
- b. Descriptions and terminologies used in society that are not scientific (Everyday language).

Some examples can be given to describe these sources listed above. For instance, both teachers and students criticized textbooks. Teachers reported that, the pictures of only green plants are given rather than a picture of blue-green algae as examples for photosynthetic organisms. However, this gives rise to misconception about photosynthetic organisms. Students considered 'only plants' or 'green plants' as making photosynthesis. Another example showing similar situation is in textbooks, the picture of cross-section of leaf is given to show photosynthesis. Any textbook demonstrating a cross-section of green stems could be found. According to teachers, this causes a common misconception, which is "Photosynthesis occurs only in leaves of plants".

Moreover, teachers complained about the curriculum, implemented in Turkey. They emphasized that the sequence of concepts makes their job difficult. Students' interviews also indicated the importance of prerequisite concepts for photosynthesis like organic compounds, energy, the chemical reactions, and the structure of plant leaf and stems.

While explaining sources of misconceptions, teachers made critics about their teaching strategies. They indicated that during instruction they sometimes summarized the topics with a figure. For example, they demonstrated the energy cycle with a figure in which plants produce oxygen and glucose by photosynthesis and animals take this oxygen and produce energy by respiration. Hence, this sort of figures causes many misconceptions about these mechanisms.

Memorization problems are common in Turkey, which in turn causes misconceptions. For example, most students, who gave the definition of photosynthesis as 'the process that plants make their food', could not identify plants' food as their products. Teachers emphasized this problem too.

Students also gain experiences out of school. In this study, it is revealed that based on these experiences students make wrong judgments, like drawing analogies between plants and animals. As an example, some of the students who considered only stem for place of photosynthesis explained her/his answer as 'our lungs are also in our body'. Furthermore, students make observations in their environment especially while raising plants. However, they could interpret these observations wrongly. For example, they told that when they put their plants in front of the window, plants die because of high intensity of light. Students do not grasp the notion of the limiting factors affecting photosynthesis.

Besides, students were also affected by their societal practices like those terminologies used in society, which are not scientifically accepted. According to teachers, the most common finding showing this situation is about the respiration of plants. Students reported that respiration occurs at night opposite to photosynthesis. Because in our society, it is commonly told not to put plants in rooms where people sleep to avoid oxygen consumption. Also, students told this experience when they were asked about the source of this knowledge.

Implications

The results of this study provided further evidence in growing body of literature emphasizing that students hold misconceptions on a variety of biological concepts. This study led to the identification of Turkish students' misconceptions about photosynthesis and respiration

in plants that students bring to classroom resulting from both their past school experiences and environment. This study recommends that teachers should be informed about students' existing conceptions and as well as the probable misconceptions. Consequently, when they identify misconceptions in their classrooms, it might be possible to help students to acquire scientifically accepted conceptions by developing alternative teaching approaches that address students' misconceptions. If students realize their misconceptions, the learning that comes on top of it will be meaningful and long-term.

This study denoted that there are some problems related to the sequence of contents given in the Turkish curriculum. In order for students to make sense of photosynthesis and respiration, the concepts such as food or organic compounds, energy, chemical reactions, and the plant anatomy should be covered initially in lessons, since students could not grasp more advanced topics without mastering the fundamental ideas. Food, energy, matter concepts were also suggested for teaching before this unit by Roth and Anderson, 1985. Curriculum developers need to know these and the misconceptions held by students in order to organize intended learning outcomes.

By now, integrated curriculum is not implemented in Turkey. However, findings of this study showed that more integration between chemistry and biology and between physics and biology is recommended in order to avoid compartmentalization of knowledge.

This study indicated that one of the sources of misconceptions is the textbook. Thus, based on the findings of this study, textbooks should be scrutinized and revised. More examples and picture presentations should be provided in order to make students visualize concepts by themselves.

Literature shows that traditional teaching methods have little impact on dispelling misconceptions. For that reason, teachers should value other methods especially conceptual change approaches and should be trained to use them. This research is not an end for research studies about students' understanding. On the basis of the findings, it may lead to a quantitative study in which the effect of different instructional methods on remediation of students' misconceptions could be explored. Moreover, the impact of curriculum implementation in Turkey could be investigated in-depth.

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Table 1

Misconceptions concerning photosynthesis and respiration in plants identified in this study

PLANT NUTRITION
1. Food for plants include water, minerals, soil, sun, CO ₂ , O ₂ , salt, inorganic materials, fertilizer, bacteria and ATP.
2. Food comes at least partially from outside of the plant.
3. Plants continue to make photosynthesis in autumn as they always do.
4. Plants die in autumn, so they don't require food.
5. Plants' food in autumn includes rain, soil, minerals taken from soil.
6. Before germination process, bean plants could make photosynthesis without green parts.
7. Before germination process, food of bean plant comprises water, CO ₂ and O ₂ , sun.
ROLE OF WATER IN PLANTS
8. Plants need water to respire
9. Plants need water to be fed.
10. Plants need water to hold in vertical position.
ROLE OF LEAVES IN PLANTS
11. Leaves serve to perform respiration.
12. Leaves' only function is to look beautiful.
13. The role of leaves is to grow.
14. The role of leaves is to discard food taken.
15. The role of leaves is to protect stem from harmful rays.
16. The role of leaves is to store starch coming from roots, soil.
17. If there were no leaves, they would become wood.
GAS EXCHANGE
18. CO ₂ is converted to O ₂ .
19. CO ₂ is cleaned up in photosynthesis.
20. CO ₂ is used up.
21. The only function of plants in world is to make environment beautiful.
22. Plants provide rain.
23. If there were no plants, harmful rays coming from sun would damage the world including humans and ozone layer.
ENERGY TRANSFORMATION
24. Plants get energy from gases, water, soil, worms and insects, fertilizer, minerals in soil.

Table 1 (continues)

DEFINITION AND IMPORTANCE OF PHOTOSYNTHESIS
25. Photosynthesis is merely a gas exchange process. 26. I don't know whether photosynthesis is important for plants or not, however it is important for us. It supplies oxygen to us. 27. Photosynthesis occurs in only leaves. 28. Photosynthesis occurs in only stem. 29. Photosynthesis occurs in roots. 30. Chemical reaction for photosynthesis includes a. $\text{CO}_2 \rightarrow \text{O}_2$ b. $\text{CO}_2 \rightarrow \text{O}_2 + \text{Energy}$ c. Chemical reaction of respiration 31. Only plants could make photosynthesis. 32. Only green plants could make photosynthesis.
ROLE OF LIGHT FOR PHOTOSYNTHESIS
33. If I increase the light intensity continuously, rate of photosynthesis would not increase after a point, because high intensity of light would give harm to plants. 34. If I increase the light intensity continuously, rate of photosynthesis would not increase because plants would make photosynthesis as needed, not more than enough. 35. If I increase the light intensity continuously, rate of photosynthesis would not increase because plants don't have capacity to take higher intensity of light.
RESPIRATION IN PLANTS
36. Photosynthesis is also a process of respiration. 37. Plants make photosynthesis, and animals perform respiration. 38. Plants perform respiration at nights. 39. Plants perform respiration during photosynthesis. 40. Plants respire whenever they want to breathe. 41. Respiration in plants occurs in leaves. 42. Respiration in plants occurs in all cells of leaves because all cells need oxygen. 43. Respiration occurs in leaves and stems. 44. Respiration occurs in roots or stems. 45. Respiration is a gas exchange process. 46. Plants make respiration to give off harmful materials. 47. Plants make respiration to take in gases needed for photosynthesis. 48. Chemical reaction for respiration in plants includes a. $\text{O}_2 + \text{Energy} \rightarrow \text{CO}_2$ b. $\text{O}_2 \rightarrow \text{CO}_2$
RELATIONSHIP BETWEEN PHOTOSYNTHESIS AND RESPIRATION IN PLANTS
49. Photosynthesis and respiration are both gas exchange events. 50. Photosynthesis is opposite to respiration. 51. Gases taken in respiration are converted to food in photosynthesis.

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Reasons of misconceptions. To analyze interviews done with teachers and students to investigate sources of misconceptions, 'start list' of codes were created based on the review of literature. Then interview transcripts were examined in order to make necessary additions, deletions, and revisions. Students' and teachers' responses were examined by two researchers based on the final codes appeared.

Results

Diagnosis of misconceptions

This study indicated that most of the Turkish students have misconceptions concerning photosynthesis and respiration in plants. The most common misconceptions identified in this study by interview technique are depicted in Table 1. Generally, results are consistent with those obtained in other countries.

Insert Table 1 here

Here are some examples of selected headings from this study:

Mostly (84% of the students) held misconception about plants' food. Students were not aware of plants' ability to produce their food. Students generally considered the materials taken from outside like water, minerals, soil, sun etc. as food for plants. They were unaware of the difference of plants from other living organisms particularly from themselves. A few examples can be given from the interview excerpts of students regarding water as plants' food:

Researcher: What is plant's food?

Student 1: Water. They need water to live. As our organism requires water, it is also necessary for their organisms to work properly.

Researcher: You told that water is food for plants. How do you know this?

Student 2: Plants could not take solid materials into their body since they don't have mouth like other living organisms. They only have pores. Thus, they will take water as food.

Moreover, when students were asked about plants' activity in autumn, only 9% of them gave satisfactory answer. One group of students reported that plants continue to make photosynthesis in autumn. Following excerpts are examples to this situation:

Researcher: In autumn, do plants make photosynthesis?

Student 1: They make. Because, they still require this process. Moreover, chlorophyll molecule does not disappear.

Student 2: They should make photosynthesis in order to survive.

Another group of students who stated that they couldn't make photosynthesis were asked to explain their food at those times. They listed their food as rain, soil, and minerals taken from soil. These responses are consistent with the responses given for the plant's food. Remaining group told: "Plants die in autumn, so they don't require food".

In addition, students' description of photosynthesis was investigated by different questions. Photosynthesis can be scientifically defined as "a process in which the autotrophic organisms produce organic materials (compounds that are produced by organisms such as carbohydrates) from inorganic materials (CO_2 and H_2O) using sunlight energy harnessed by the chlorophyll". Students' answers were analyzed according to this definition.

Some students' responses (25%) indicated that they regarded photosynthesis as only a gas exchange process. Typical answers were "By the help of sun light, CO_2 is converted into O_2 ", "the process of taking in CO_2 and giving out O_2 in the daylight by plants", "the ability of taking in CO_2 and giving out O_2 ". Moreover, it was revealed that that half of the students could define photosynthesis satisfactorily, however when they were asked further questions in order to

investigate their understanding, their answers showed that they had only memorized a definition without making sense of the concept.

When students were asked, "Where does photosynthesis take place?", approximately 26% of them gave the scientifically accepted answer. On the other hand, more than half of the students told that photosynthesis occurs at only leaves; the remaining replied 'only stem' as site for photosynthesis. Here are the examples from interview excerpts:

- Student 1: Since stomata or gas exchange pores are in the leaves, it should occur there.
- Student 2: Since the chlorophyll is in the leaves, it should occur there.
- Student 3: In stem...because I identify plants like people. As we have our lungs within our body, they have their similar organs in their stem too.
- Student 4: It can't be at roots because sunlight can't reach there; it can't be at leaves because it makes excretion from there so that it should be at stems

Additionally, almost all students knew the importance of light for photosynthesis and the factors that affect the rate of photosynthesis. However, they had problems with the concept of limiting factor. They were asked, "If I increase the light intensity continuously, does also rate of photosynthesis increase accordingly? What happens? Why?" 20% of the students gave correct response which was "If other factors affecting photosynthesis are not adequate, it will not increase." On the other hand, half of them told that it would not increase because high intensity of light would give harm to plant after some point. Examples to this situation are given as follows:

- Student 1: Once I was growing a plant and it took too much sunlight, it began to dry. When I took it from sunlight, it turns to normal.
- Student 2: I thought myself. It is also a living organism. When I take high intensity of light, it makes a bad effect to me, thus it will also make bad effect to the plant.
- Student 3: It will not increase because it will make photosynthesis as needed, not more than enough

Moreover, students were asked series of questions in order to explore their understanding of respiration. Most of the students (84% of total) knew that plants make respiration. However, more than half stated that respiration in plants occurs at nights. Other alternative responses were 'during photosynthesis' and 'whenever breathing is required'.

Exploring sources of misconceptions

Broadly speaking, interviews with students and teachers demonstrated that the sources of these misconceptions are:

1. School Experience

- a. Instruction including textbook effect, transmission by teacher, and inadequacy of instruction.
- b. Inadequacy of Curriculum
- c. Memorization of isolated pieces of information.
- d. Wrong descriptions of the observations in school.
- e. Students' experiences related to other science courses including primary and secondary school experiences.

2. Social practices

- a. Students' own judgments based on their observations.
- b. Descriptions and terminologies used in society that are not scientific (Everyday language).

Some examples can be given to describe these sources listed above. For instance, both teachers and students criticized textbooks. Teachers reported that, the pictures of only green plants are given rather than a picture of blue-green algae as examples for photosynthetic organisms. However, this gives rise to misconception about photosynthetic organisms. Students considered 'only plants' or 'green plants' as making photosynthesis. Another example showing similar situation is in textbooks, the picture of cross-section of leaf is given to show photosynthesis. Any textbook demonstrating a cross-section of green stems could be found. According to teachers, this causes a common misconception, which is "Photosynthesis occurs only in leaves of plants".

Moreover, teachers complained about the curriculum, implemented in Turkey. They emphasized that the sequence of concepts makes their job difficult. Students' interviews also indicated the importance of prerequisite concepts for photosynthesis like organic compounds, energy, the chemical reactions, and the structure of plant leaf and stems.

While explaining sources of misconceptions, teachers made critics about their teaching strategies. They indicated that during instruction they sometimes summarized the topics with a figure. For example, they demonstrated the energy cycle with a figure in which plants produce oxygen and glucose by photosynthesis and animals take this oxygen and produce energy by respiration. Hence, this sort of figures causes many misconceptions about these mechanisms.

Memorization problems are common in Turkey, which in turn causes misconceptions. For example, most students, who gave the definition of photosynthesis as 'the process that plants make their food', could not identify plants' food as their products. Teachers emphasized this problem too.

Students also gain experiences out of school. In this study, it is revealed that based on these experiences students make wrong judgments, like drawing analogies between plants and animals. As an example, some of the students who considered only stem for place of photosynthesis explained her/his answer as 'our lungs are also in our body'. Furthermore, students make observations in their environment especially while raising plants. However, they could interpret these observations wrongly. For example, they told that when they put their plants in front of the window, plants die because of high intensity of light. Students do not grasp the notion of the limiting factors affecting photosynthesis.

Besides, students were also affected by their societal practices like those terminologies used in society, which are not scientifically accepted. According to teachers, the most common finding showing this situation is about the respiration of plants. Students reported that respiration occurs at night opposite to photosynthesis. Because in our society, it is commonly told not to put plants in rooms where people sleep to avoid oxygen consumption. Also, students told this experience when they were asked about the source of this knowledge.

Implications

The results of this study provided further evidence in growing body of literature emphasizing that students hold misconceptions on a variety of biological concepts. This study led to the identification of Turkish students' misconceptions about photosynthesis and respiration

in plants that students bring to classroom resulting from both their past school experiences and environment. This study recommends that teachers should be informed about students' existing conceptions and as well as the probable misconceptions. Consequently, when they identify misconceptions in their classrooms, it might be possible to help students to acquire scientifically accepted conceptions by developing alternative teaching approaches that address students' misconceptions. If students realize their misconceptions, the learning that comes on top of it will be meaningful and long-term.

This study denoted that there are some problems related to the sequence of contents given in the Turkish curriculum. In order for students to make sense of photosynthesis and respiration, the concepts such as food or organic compounds, energy, chemical reactions, and the plant anatomy should be covered initially in lessons, since students could not grasp more advanced topics without mastering the fundamental ideas. Food, energy, matter concepts were also suggested for teaching before this unit by Roth and Anderson, 1985. Curriculum developers need to know these and the misconceptions held by students in order to organize intended learning outcomes.

By now, integrated curriculum is not implemented in Turkey. However, findings of this study showed that more integration between chemistry and biology and between physics and biology is recommended in order to avoid compartmentalization of knowledge.

This study indicated that one of the sources of misconceptions is the textbook. Thus, based on the findings of this study, textbooks should be scrutinized and revised. More examples and picture presentations should be provided in order to make students visualize concepts by themselves.

Literature shows that traditional teaching methods have little impact on dispelling misconceptions. For that reason, teachers should value other methods especially conceptual change approaches and should be trained to use them. This research is not an end for research studies about students' understanding. On the basis of the findings, it may lead to a quantitative study in which the effect of different instructional methods on remediation of students' misconceptions could be explored. Moreover, the impact of curriculum implementation in Turkey could be investigated in-depth.

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Table 1

Misconceptions concerning photosynthesis and respiration in plants identified in this study

PLANT NUTRITION
1. Food for plants include water, minerals, soil, sun, CO ₂ , O ₂ , salt, inorganic materials, fertilizer, bacteria and ATP.
2. Food comes at least partially from outside of the plant.
3. Plants continue to make photosynthesis in autumn as they always do.
4. Plants die in autumn, so they don't require food.
5. Plants' food in autumn includes rain, soil, minerals taken from soil.
6. Before germination process, bean plants could make photosynthesis without green parts.
7. Before germination process, food of bean plant comprises water, CO ₂ and O ₂ , sun.
ROLE OF WATER IN PLANTS
8. Plants need water to respire
9. Plants need water to be fed.
10. Plants need water to hold in vertical position.
ROLE OF LEAVES IN PLANTS
11. Leaves serve to perform respiration.
12. Leaves' only function is to look beautiful.
13. The role of leaves is to grow.
14. The role of leaves is to discard food taken.
15. The role of leaves is to protect stem from harmful rays.
16. The role of leaves is to store starch coming from roots, soil.
17. If there were no leaves, they would become wood.
GAS EXCHANGE
18. CO ₂ is converted to O ₂ .
19. CO ₂ is cleaned up in photosynthesis.
20. CO ₂ is used up.
21. The only function of plants in world is to make environment beautiful.
22. Plants provide rain.
23. If there were no plants, harmful rays coming from sun would damage the world including humans and ozone layer.
ENERGY TRANSFORMATION
24. Plants get energy from gases, water, soil, worms and insects, fertilizer, minerals in soil.

Table 1 (continues)

DEFINITION AND IMPORTANCE OF PHOTOSYNTHESIS	
25. Photosynthesis is merely a gas exchange process.	
26. I don't know whether photosynthesis is important for plants or not, however it is important for us. It supplies oxygen to us.	
27. Photosynthesis occurs in only leaves.	
28. Photosynthesis occurs in only stem.	
29. Photosynthesis occurs in roots.	
30. Chemical reaction for photosynthesis includes	
a. $\text{CO}_2 \rightarrow \text{O}_2$	
b. $\text{CO}_2 \rightarrow \text{O}_2 + \text{Energy}$	
c. Chemical reaction of respiration	
31. Only plants could make photosynthesis.	
32. Only green plants could make photosynthesis.	
ROLE OF LIGHT FOR PHOTOSYNTHESIS	
33. If I increase the light intensity continuously, rate of photosynthesis would not increase after a point, because high intensity of light would give harm to plants.	
34. If I increase the light intensity continuously, rate of photosynthesis would not increase because plants would make photosynthesis as needed, not more than enough.	
35. If I increase the light intensity continuously, rate of photosynthesis would not increase because plants don't have capacity to take higher intensity of light.	
RESPIRATION IN PLANTS	
36. Photosynthesis is also a process of respiration.	
37. Plants make photosynthesis, and animals perform respiration.	
38. Plants perform respiration at nights.	
39. Plants perform respiration during photosynthesis.	
40. Plants respire whenever they want to breathe.	
41. Respiration in plants occurs in leaves.	
42. Respiration in plants occurs in all cells of leaves because all cells need oxygen.	
43. Respiration occurs in leaves and stems.	
44. Respiration occurs in roots or stems.	
45. Respiration is a gas exchange process.	
46. Plants make respiration to give off harmful materials.	
47. Plants make respiration to take in gases needed for photosynthesis.	
48. Chemical reaction for respiration in plants includes	
a. $\text{O}_2 + \text{Energy} \rightarrow \text{CO}_2$	
b. $\text{O}_2 \rightarrow \text{CO}_2$	
RELATIONSHIP BETWEEN PHOTOSYNTHESIS AND RESPIRATION IN PLANTS	
49. Photosynthesis and respiration are both gas exchange events.	
50. Photosynthesis is opposite to respiration.	
51. Gases taken in respiration are converted to food in photosynthesis.	